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ENERGETIC ELECTRON DETECTORS FOR THE METEOSAT SATELLITE  
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MULLARD SPACE SCIENCE LAB A D JOHNSTONE ET AL.  
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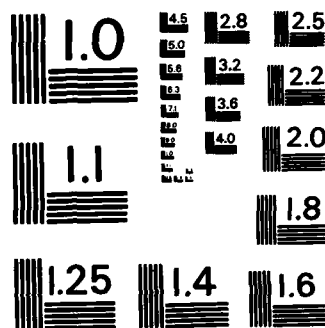
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# UNIVERSITY COLLEGE LONDON

DEPARTMENT OF PHYSICS AND ASTRONOMY

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ENERGETIC ELECTRON DETECTORS FOR THE METEOSAT SATELLITE

TECHNICAL SUPPORT

A.D. Johnstone  
G.L. Wrenn

AFOSR - 80 - 0124A FINAL REPORT JULY 1982

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## MULLARD SPACE SCIENCE LABORATORY

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TECHNICAL SUPPORT.

A.D. Johnstone

G.L. Wrenn

Mullard Space Science Laboratory  
University College London  
Holmbury St. Mary  
Dorking, Surrey, England.



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# Energetic Electron Detectors for the Meteosat Satellite

## Technical Support

### FINAL REPORT

#### 1. Introduction

The ESA geosynchronous spacecraft for meteorological observations, Meteosat F1, launched in November 1977, suffered from a number of operational anomalies which were attributed to spacecraft charging.<sup>(1)</sup> An extensive series of experiments carried out on the ground appeared to confirm this interpretation of the flight data<sup>(2)</sup> so some modifications were made to the Meteosat F2 spacecraft. These modifications had three purposes; first to reduce the level spacecraft charging, particularly differential charging, then to reduce the susceptibility of the spacecraft to arcing and finally to monitor the plasma environment of the spacecraft and the occurrence of arcing events.

The monitor of the plasma environment was supplied to ESA by the U.S. Air Force Geophysics Laboratory in the shape of the SSJ/3 sensor as constructed by Emmanuel College, Boston for the SCATHA and DMSP programmes. Under the contract, for which this is the final report, Mullard Space Science Laboratory undertook to provide technical support as necessary for Emmanuel College during integration of the instrument with the spacecraft and to prepare for the data analysis.

Due to delays in the development of the Ariane launch vehicle the launch of Meteosat F2 was delayed by a year. An interim report on the progress under the contract was issued in May 1981 and the period of the contract was extended to 31st March 1982.

Meteosat F2 was launched on 19th June 1981 and arrived on station at the Greenwich meridian on 21st July 1981. The SSJ/3 electron

spectrometer was turned on and commissioned on the 28th July 1981 from the European Space Operations Centre at Darmstadt by Dr. D. Parsignault of Emmanuel College and Dr. A. Johnstone of Mullard Space Science Laboratory. Since that time the instrument has operated almost continuously returning good quality data.

A preliminary report on the data has been published in the ESA Bulletin of February 1982<sup>(3)</sup>.

## 2. Integration Activities

As explained in the interim report, Emmanuel College were able to cover the integration activities and in the event did not call upon assistance from MSSL as was foreseen. Three liaison visits were made by Dr. A. Johnstone for the purpose of reviewing the installation of the instrument with representatives of Emmanuel College at the contractors Aerospatiale, Cannes and to coordinate the data processing plans at ESOC and the Earth Observations Programme Office in Toulouse.

### 3. Data Processing

### 3.1. Routine Processing

Preparations for the data processing were carried out under this contract and its extension to 31st March 1982. Since launch, routine processing at MSSL has been supported by a contract from ESA.

ESOC produces a data tape containing all the data from SSJ/3 and the Electrostatic Event Monitor for each calendar month. One copy is sent to MSSL and another to Emmanuel College. MSSL produces daily summary plot (Figure 1) and a monthly summary (Figure 2) for the relevant Meteosat data and additional geophysical data. Copies are sent to Emmanuel College as well as ESA.

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### 3.2. Processing Problems

A problem arose with the data summaries in that initially the generated spectra were not smooth and appeared unrealistic. Dr. Wrenn visited ESOC between the 3rd and 6th November 1981 and studied real time data in order to understand the problem. An error in the data format specification was discovered and corrected.

The SSJ/3 outputs sixteen 11 bit counts over a period of four telemetry formats (100.7 seconds) to make up a complete spectrum. Each 11 bit compressed count consists of a 4 bit exponent (X) and a 7 bit mantissa (Y). Counts are decoded according to the relationship:

$$\text{Count} = (Y + 128) * 2^X - 129$$

In each format (12.58 seconds) four of the counts C1, C2, C3 and C4 were transmitted in three 16 bit data words 'Data A', 'Data B' and 'Data C'. The construction of the words is as follows:

Data A (W16 F11 S028) Sync,X1,Y1,X3

Data B (W16 F27 S053) Sync,X2,Y2,X4

Data C (W16 F28 S054) Sync,Y3,Y4,Sync      Each Sync being 1 bit.

C1, C2, C3 and C4 are determined as above but the mistake was in relating these counts to the sixteen energies E1 thru E16. The specification gave:

C1 = E02, E04, E06, E03

C2 = E01, E03, E05, E09

C3 = E10, E12, E14, E16



C4 = E09, E11, E13, E15 for a succession of four formats.

Consideration of the energy stepping and count sampling synchronisation showed that C1 and C3 were wrongly specified, the correct order being:

C1 = E03, E02, E04, E06

C3 = E16, E10, E12, E14

Following the correction realistic and consistent energy spectra are obtained.

The conversion from counts to absolute number fluxes depends upon available calibration data and this has been obtained from pre-launch tests and experimental results from similar instruments. A cross calibration between the two detectors (LO and HI) can be done with the in-flight data because there is an overlap between channels E08 and E09 which both have centre energies close to 1 keV. Comparisons of these two channels has shown that E09 consistently undercounts by a factor of ~1.7 and this leads to the conclusion that the HI detector was degraded at launch. The geometric factors appropriate to each channel have now been specified as follows, but Emmanuel College will be studying this problem in more detail.

Centre Energy (LO) (eV)	Integrated Geometric Factor (cm <sup>2</sup> sr eV)	Centre Energy (HI) (eV)	Integrated Geometric Factor (cm <sup>2</sup> sr eV)
E01 49.0	0.00172	E09 984.	0.0634
E02 75.4	0.00353	E10 1508.	0.0872
E03 115.8	0.00565	E11 2316.	0.117
E04 117.	0.00842	E12 3540.	0.164
E05 274.	0.0130	E13 5480.	0.218
E06 418.	0.0200	E14 8360.	0.292
E07 644.	0.0317	E15 12880.	0.388
E08 990.	0.0474	E16 19800.	0.480

### 3.3 Current Status

The SSJ/3 instrument aboard Meteosat 2 is now near to completing one year of operation. No further degradation has been detected and data of high quality continues to flow. MSSSL have distributed daily and monthly summaries for August 1981 thru April 1982 and Emmanuel College have received data tapes to cover the same period.

## 4. Scientific Results

### 4.1. Operational Anomalies

A number of design changes were made for Meteosat F2 after the problems of Meteosat F1. The S/C charging monitor experiments with associated harness were added; both sides of thermal shields were grounded to structure; relays were introduced into the switching circuits, the VHF converter grounding was improved, and telecommand

circuits for the converters were replaced. During the first eight months in orbit the number of 'arcing' type anomalies was only 4 on F2 compared with 64 in the first eight months of F1. It is worth noting that the thermal design of the satellite was in no way compromised; in fact the F2 performance was slightly better than F1.

The SSJ/3 instrument has successfully monitored the charging current of energetic electrons incident to the spacecraft and it has been possible to establish that those few anomalies which occurred on Meteosat F2 are generally not a consequence of arcing.<sup>(3)</sup> On the other hand the data have been used as part of an investigation into the serious operational problems encountered by Marecs A during February and March 1982.

Marecs A is an ESA operational spacecraft in geosynchronous orbit designed for maritime communications. It is stationed at a longitude of  $25^{\circ}\text{W}$ ; i.e.  $25^{\circ}$  away from Meteosat. Its operational problems occurred during a period of intense geomagnetic activity. In fact the month of February 1982 was the most active month geomagnetically since November 1960.

Here it was possible to show a very clear correlation between the Marecs anomalies and enhanced electron fluxes at Meteosat, despite the difference in longitude.

#### 4.2. Eclipse date.

There is no evidence that Meteosat F2 as a whole charges to significant voltages but the electron fluxes during times of eclipse when the satellite is in the shadow of the Earth and no photoelectrons are being emitted, are very interesting. Count rates in the L0 energy channels are often increased by as much as two orders of magnitude. Such increases are usually confined to a single channel but the specific channel changes through the eclipse, moving gradually to higher energy. It is believed that this is evidence for differential

charging on the satellite surface with secondary electrons emitted from a region of high (~800) voltage being accelerated into the detectors. Figure 3 shows the typical build-up of these strange spectra, umbra entry was at 23:21 with umbra exit at 00:28. The undisturbed spectra at 23.17 (before) and 00:33 (after) are relatively structureless but the intermediate curves feature a strong mono-energetic electron component which must be of spacecraft origin. Secondary electrons clearly play a vital role in the spacecraft charging process and detailed study of this data should permit much improved modelling of the in-orbit situation.

Secondary yield is a function of primary energy and Whipple<sup>(4)</sup> gives an equation for the angle averaged yield as:

$$d = \frac{2.228 \cdot d_m}{Q} \left( \frac{E_m}{E} \right)^{0.35} (Q - 1 + e^{-Q})$$

where

$$Q = 2/28 \cdot (E/E_m)^{1.35}$$

The maximum yield  $d_m$  and the energy at maximum yield  $E_m$  varies with the surface but for normal spacecraft materials  $E_m$  is a few hundred eV and  $d_m$  is in the range 1 to 3. The energy spectrum of the plasmashet electrons is thus an important variable, an entry into the plasmashet is usually characterised by energy dispersion as illustrated by Figure 4. The energy (or temperature) gradient appearing at the inner edge of the plasmashet obviously is important to the understanding of charging problems as well as magnetospheric physics.

### 4.3. Magnetospheric boundary motions.

Three characteristic plasma populations are readily identified in the summary plots. During the early evening the spacecraft passes

from the plasmasphere to the plasmasheet through a relatively sharp boundary. Figure 5 shows the correlation between the local time at which the boundary is crossed and the Kp value. In quiet times the boundary remains fixed in space but during disturbed times it moves towards the Earth and the entry point moves to earlier local times. Comparison of entry times at Meteosat F2 with those at Geos 2 or Scatha enable a determination of the velocity of motion of the boundary. One hour local per hour Universal is a typical value. This simply demonstrates the value of the SSJ/3 data set for magnetospheric studies.

When the solar wind pressure increases to very high levels, as it did several times during February and March 1982 the magnetopause moves inside the Meteosat orbit. Then magnetosheath electrons are detected in the LO energy channels. The poor temporal resolution prevents a detailed study of these fluxes but the information on the boundary variations and magnetospheric compression is valuable.

## 5. Conclusions

### 5.1. Spacecraft Charging

There are two main lessons to be learned from the Meteosat data. First that even relatively small changes in spacecraft design can greatly reduce the susceptibility of a spacecraft to anomalies caused by charging. This is demonstrated by the relative performance of Meteosat F1, F2 and Marecs A. Secondly, data provided by a simple reliable instrument like the SSJ/3 can play an important role in monitoring the geosynchronous plasma environment, the environment in which many operational spacecraft are located.

Some puzzles remain. Meteosat anomalies, previously attributed to spacecraft charging, have occurred at times when there is little variation in the plasma to indicate a cause.

## 5.2. Magnetospheric Physics

Although the Meteosat data have poor temporal resolution compared with specialised magnetospheric instruments the data are likely to prove extremely valuable. Two aspects are important; the continuity of the data set in a straightforward operational mode and its spatial relationship to GEOS-2 and SCATHA spacecraft.

## 6. Future Work

Routine operations and data processing will continue at least until July 1983 if spacecraft and instrument continue operating reliably. Extension beyond that time has not yet been discussed.

At MSSL we propose to continue working on the scientific analysis of the data in collaboration with Emmanuel College and the Air Force Geophysics Laboratory.

## 7. Recommendation

The daily monitoring of plasmasheet electrons is very useful to a great many workers in geophysics and the data set should be contributed to the World Data Centre.

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3. Johnstone, A.D., G.L. Wrenn, A. Huber, D. Hoge. First Results from Meteosat-2 Discharge Experiments, ESA Bulletin, 29, 84-89, February 1982.
4. Whipple, E.C. Potentials of surfaces in space. Rep. Prog. Phys., 44, 1197-1250, 1981.

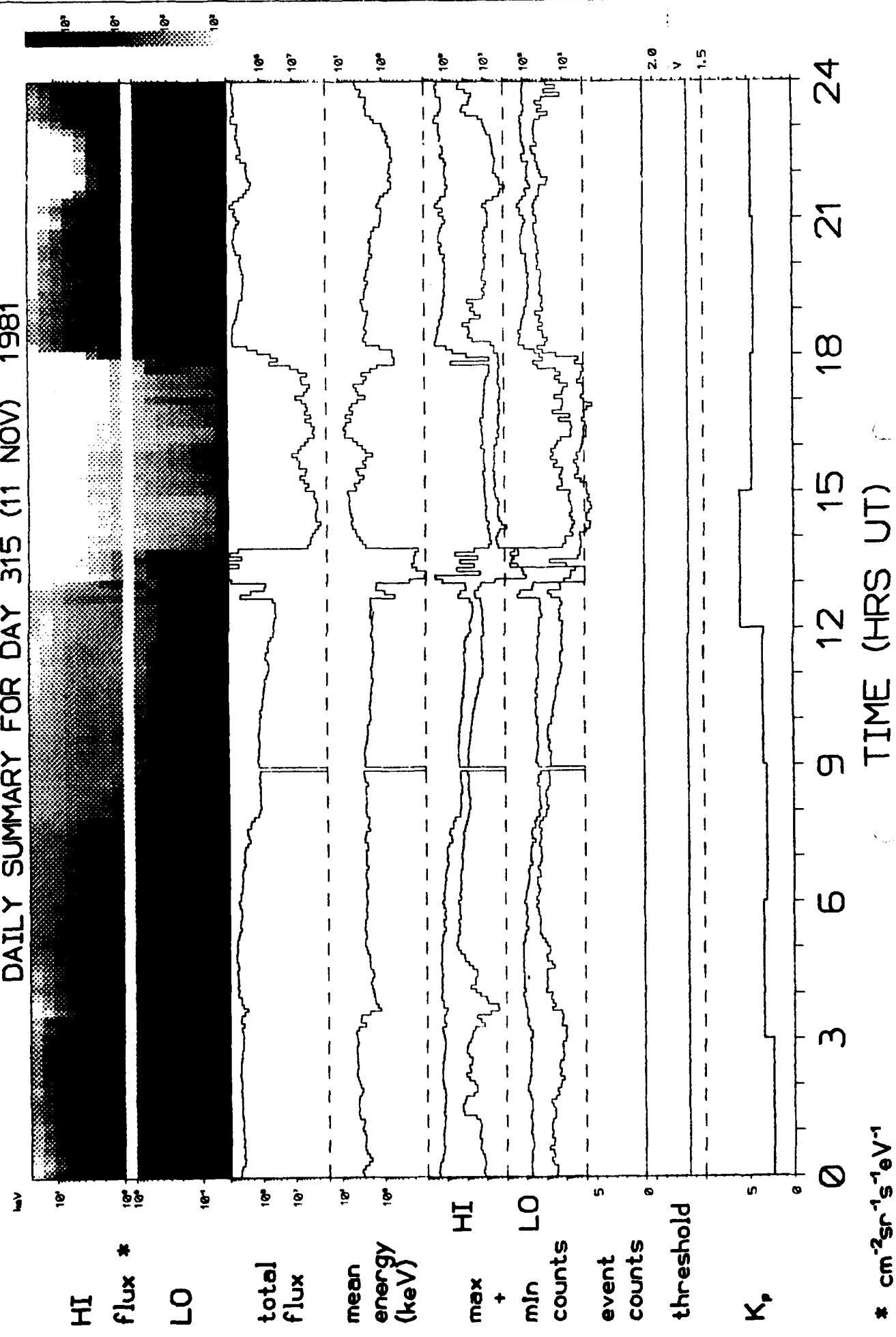
Figure Captions

- Fig. 1. Daily summary for November 11th 1981. Such summaries are available for every day since August 1st 1981.
- Fig. 2. Monthly summary for May 1982. Such summaries are available for every month since August 1981.
- Fig. 3. Electron energy spectra taken during eclipse; umbra entry was at 23:21, umbra exit at 00:28.
- Fig. 4. Energy dispersion at a plasmashet entry, lower energies (temperatures) occur near the inner edge.
- Fig. 5. Dependence of plasmashet entry time upon the planetary geomagnetic index, kp; data from August to October 1981.



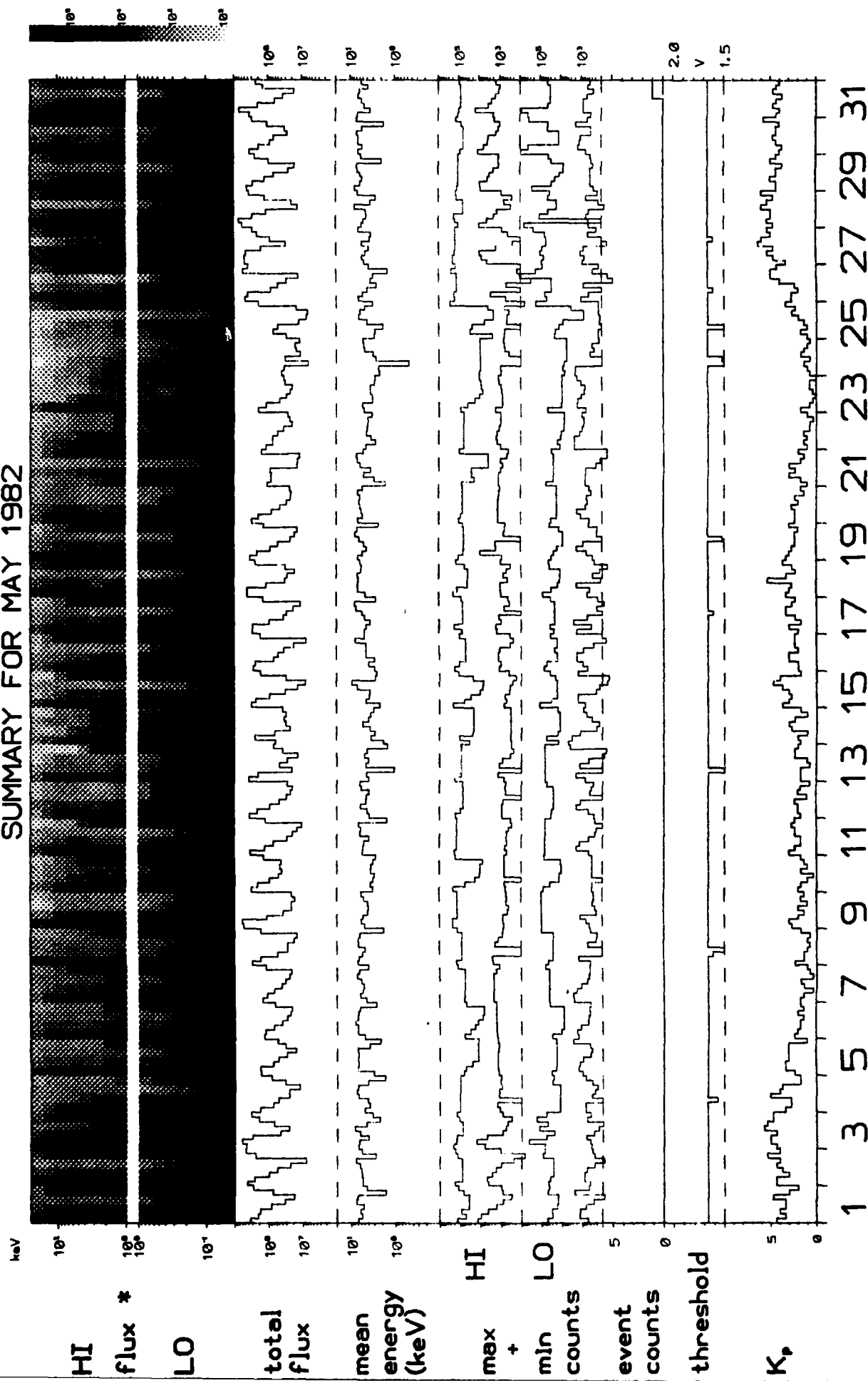
# METEOSAT F2 SPACECRAFT CHARGING MONITORS

## DAILY SUMMARY FOR DAY 315 (11 NOV) 1981

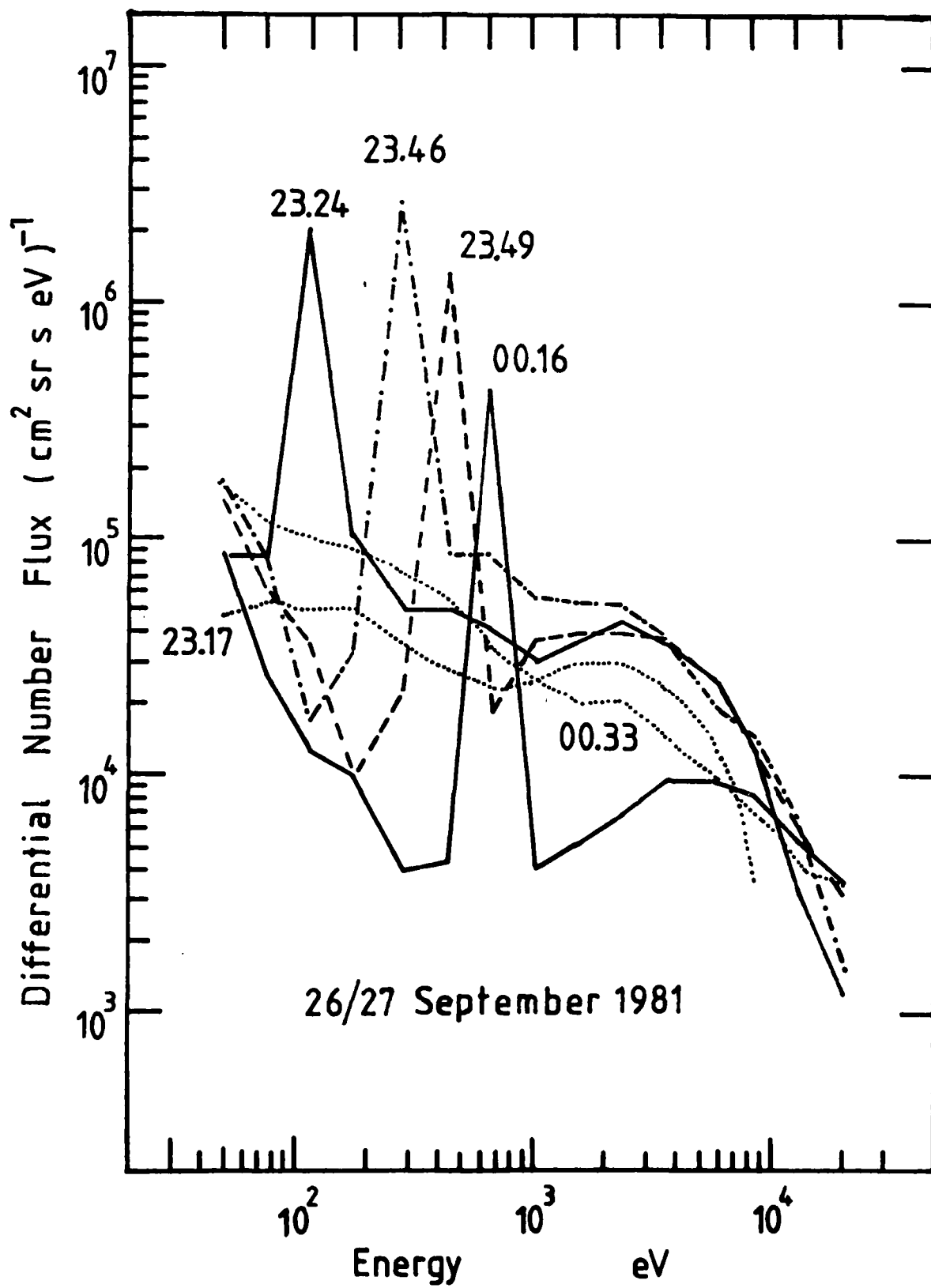


# METEOSAT F2 SPACECRAFT CHARGING MONITORS

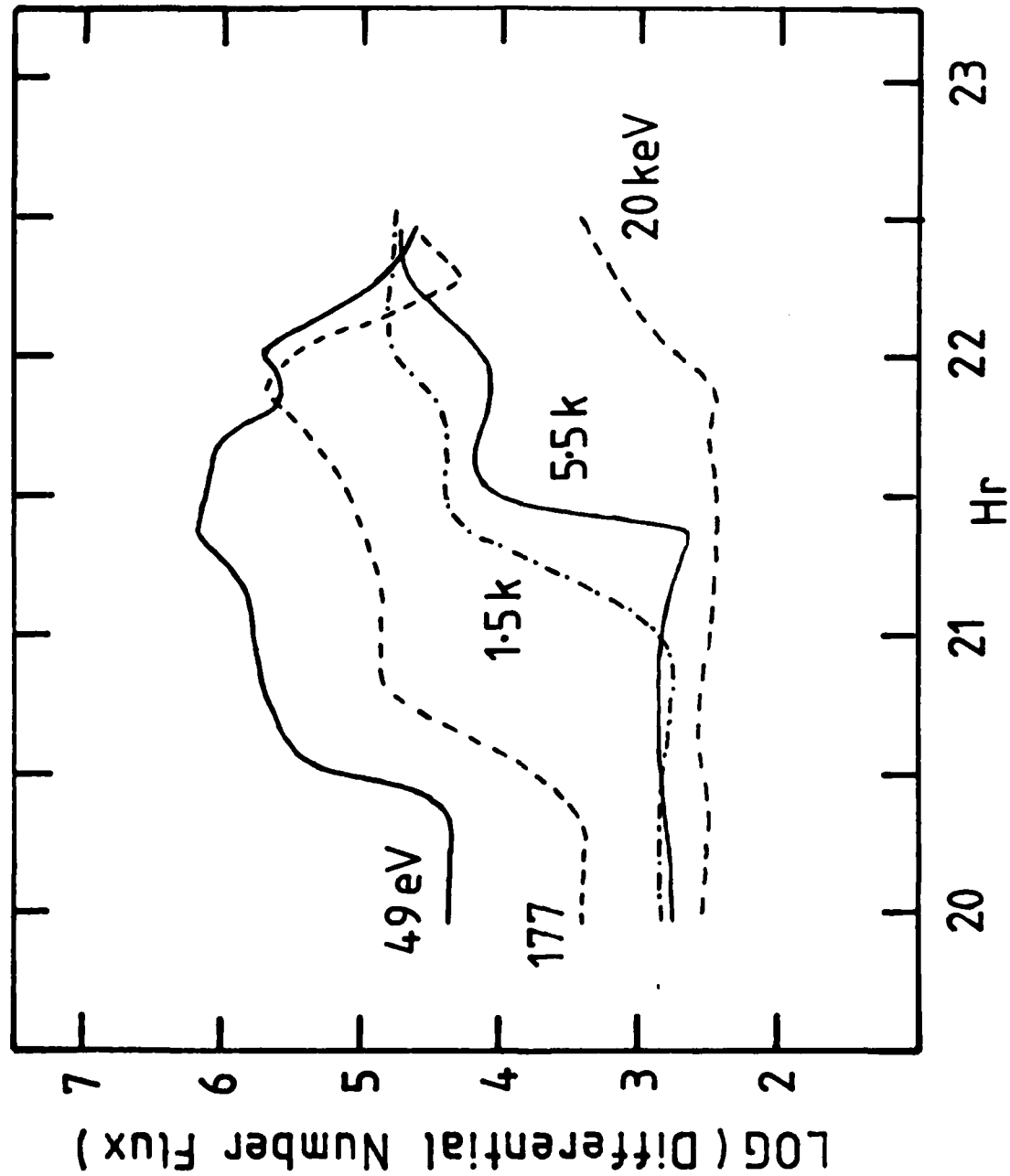
SUMMARY FOR MAY 1982



\*  $\text{cm}^2\text{sr}^{-1}\text{s}^{-1}\text{eV}^{-1}$



METEOSAT 2 PLASMASHEET ENTRY



16 NOV 1981

$K_p = 4-$

